

**Comparative Assessment of 3D Models Accuracy at Building Level  
Pleiades and WorldView-1 stereo pairs imagery**

**Pléiades Days 2014 / 3D Thematic Session**

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- Benefits and purpose of use
- Area of Interest Characteristics
- Satellite imagery & Other Input data
- Technical and scientific approach & methods
- Results:
  - Qualitative Assessment
  - Quantitative Findings
- Concluding Remarks



## Technology background

- ❑ During the last decades a significant number of Very High Resolution (VHR) satellite data with spatial resolution higher than 1 meter are available for public use.
- ❑ The production of 3D surface models in urban fabric areas, using satellite (VHR) stereo data, is a popular theme in geo-sciences.

## Requirement

- ❑ Certain public and/or private domain bodies need accurate information of height changes at building level in the context of monitoring or planning activities.

## An Approach...

- ❑ Operational Production/ Update of accurate 3D surface models accounting for existing buildings' geometries.
- ❑ Satellite platform – free methodology and consistency of the results

## A case

- ❑ A comparative assessment referring to the outcome of satellite stereo-pairs processing acquired by the Pleiades and the WorldView-1 sensors.
- ❑ Buildings' footprints geometries integration in the process; Production of 3D urban fabric models through focusing on buildings (processing and results' evaluation).



## Eleonas district

Near to Athens' city center

17.400 acres

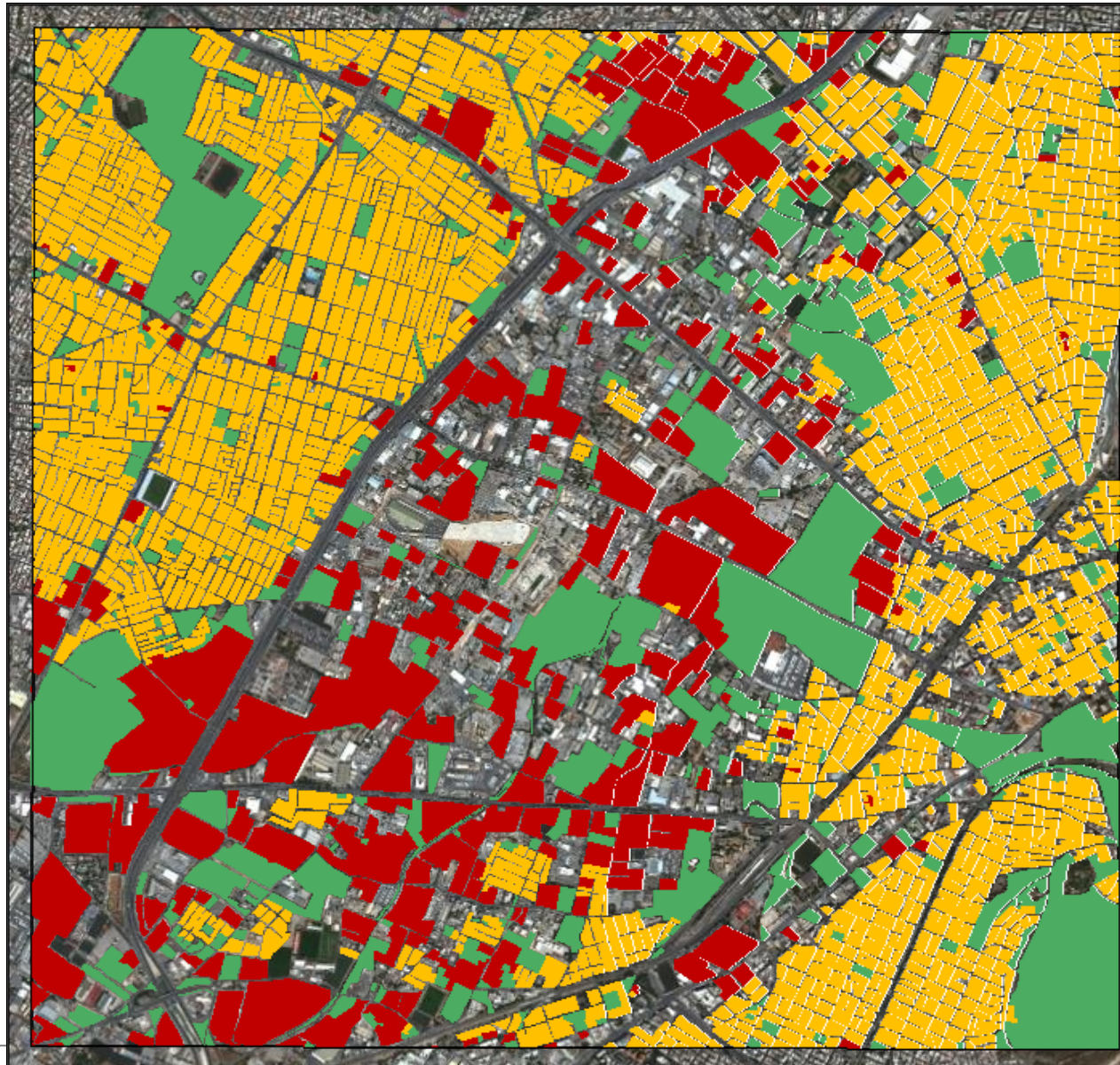
### Financial Activities

- ✓ Industrial plants
- ✓ Light manufacture units
- ✓ Commercial activities

### Urban fabric (residential)

### Urban environment enhancement opportunities

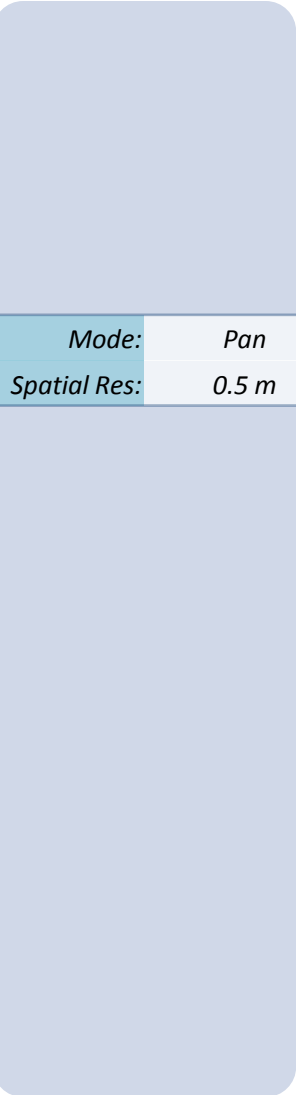
- ✓ Non used - Open Spaces
- ✓ Scattered Byzantine & Contemporary Monuments
- ✓ Low quality road network
- ✓ Green Areas





## WorldView1

Acquisition Date:	<b>2009.07.19</b>	
Dynamic Range:	11-bits	
Sun Azimuth (mean):	Scene 1	Scene 2
	134.00	134.40
Sun Elevation (mean):	Scene 1	Scene 2
	67.40	67.50
Off-Nadir (mean):	Scene 1	Scene 2
	22.20	28.80



Mode:	Pan
Spatial Res:	0.5 m

## Pleiades

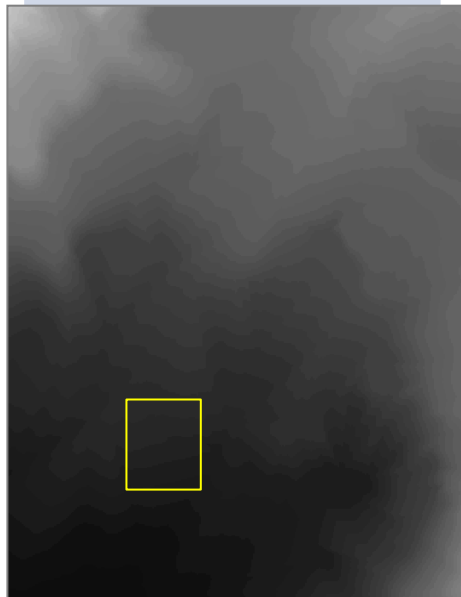
Acquisition Date:	<b>2012.12.25</b>	
Dynamic Range:	12-bits	
Sun Azimuth (middle):	Scene 1	Scene 2
	163.13	162.89
Sun Elevation (middle):	Scene 1	Scene 2
	26.91	26.85
Across track (middle):	Scene 1	Scene 2
	1.96	5.85



shadows



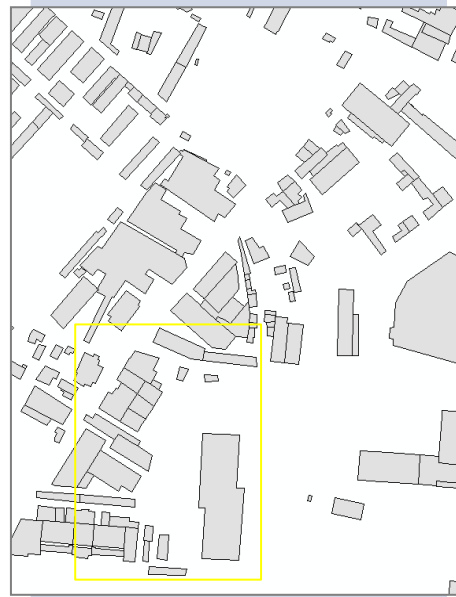
DTM



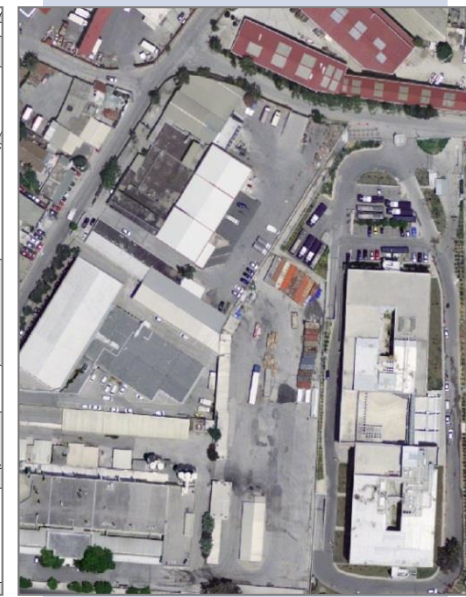
DSM



Building footprints



Orthophotos



Format: Raster

Raster

Vector

Raster

Ref. year(s): 2000

2007

2007,09,11

2007

Accuracy: (Z) 2,5 m

(Z) 1 m

(X, Y) 1 m

(X, Y) 0,6 m


















Spat. Res: 10 m

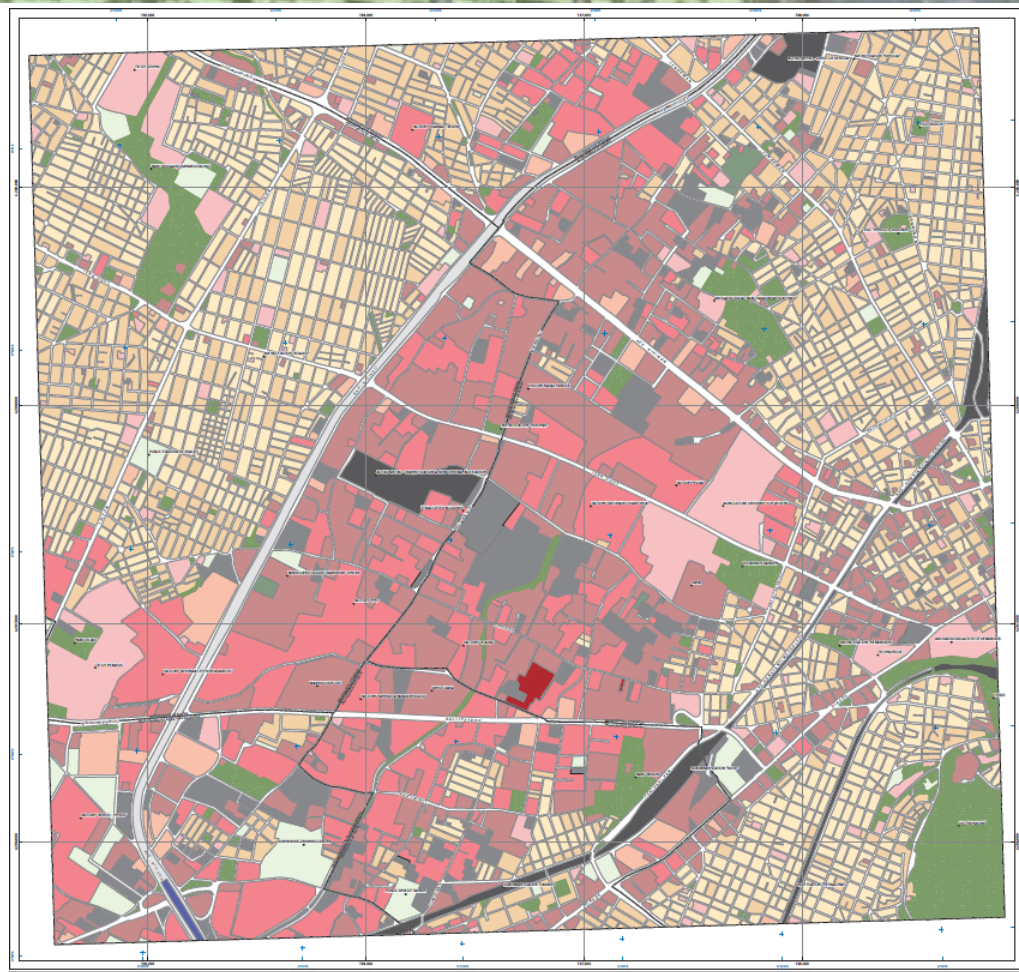
0,2 m

-

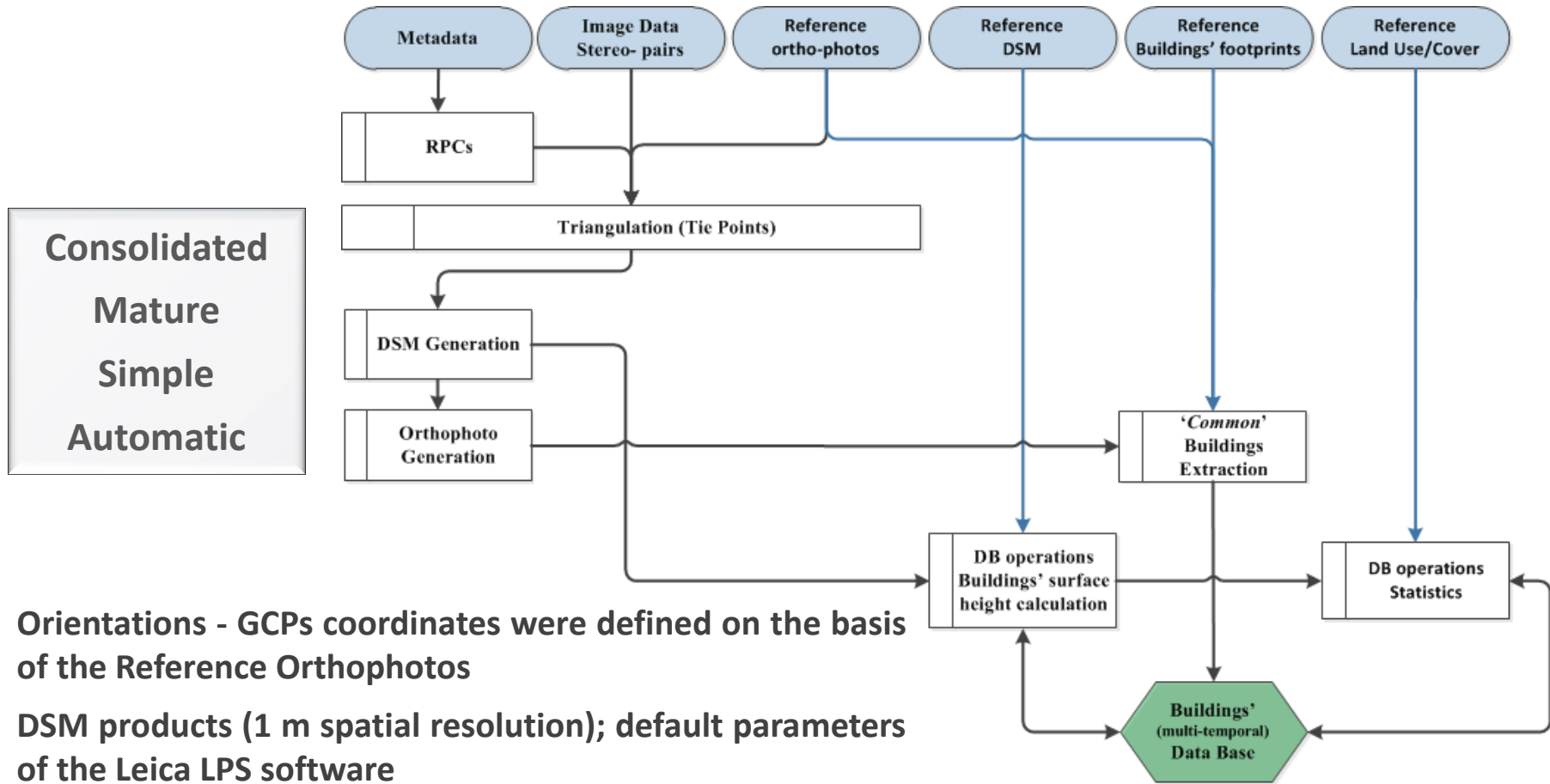
2 m



-  Dense Urban Fabric (P.B.A. > 60%)
-  Medium-Low Urban Fabric (P.B.A.: 10% - 60%)
-  Temporary Housing
-  Industrial areas
-  Commercial areas
-  Public, Military and Private Services
-  Education, Culture, Places of worship and Health Services
-  Fast transit roads and associated land
-  Other permanent roads and associated land
-  Non asphalted roads and associated land
-  Railways and associated land
-  Construction sites
-  Land without current use
-  Green urban areas
-  Sports and leisure facilities
-  Agricultural + Semi-natural areas + Wetlands
-  Water bodies



**URBAN ATLAS NOMENCLATURE**  
**MMU 0,05 HA**



Consolidated  
Mature  
Simple  
Automatic

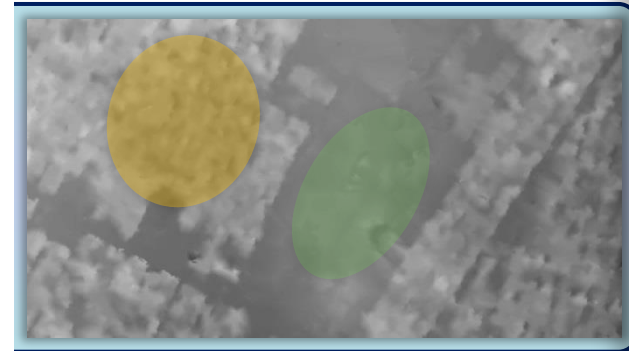
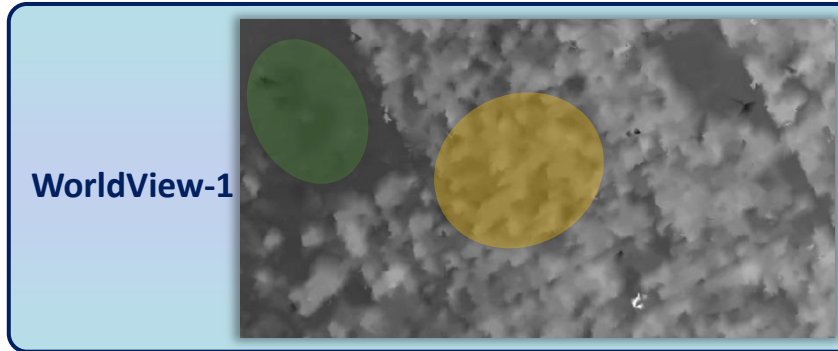
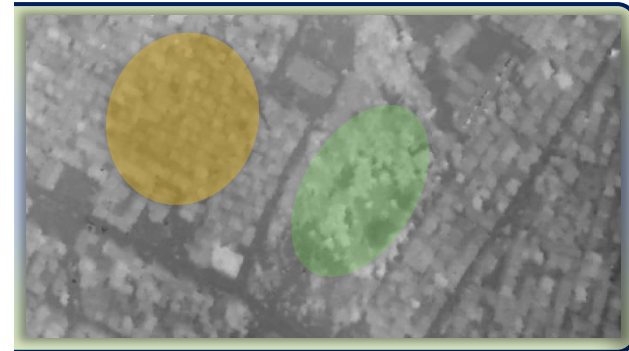
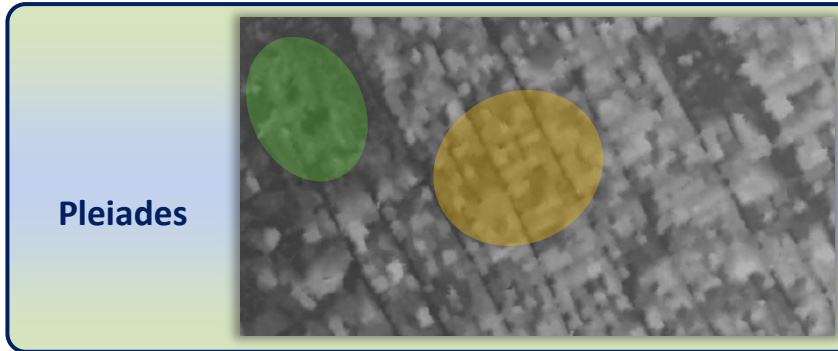
- ✓ Orientations - GCPs coordinates were defined on the basis of the Reference Orthophotos
- ✓ DSM products (1 m spatial resolution); default parameters of the Leica LPS software
- ✓ Main artefacts (spikes, holes), represent the ~ 1,5% of the AOI (both data sets)
- ✓ ~ 28.000 buildings present at the multi-date imagery; reference data/2007, WorldView-1/2009 & Pleiades/2012
- ✓ The average height of the buildings was calculated and accounted for the analysis





## Dense Urban Fabric

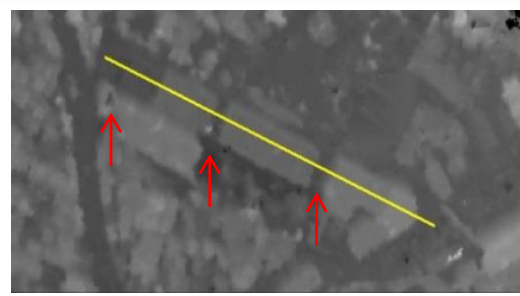
## Green Urban Areas



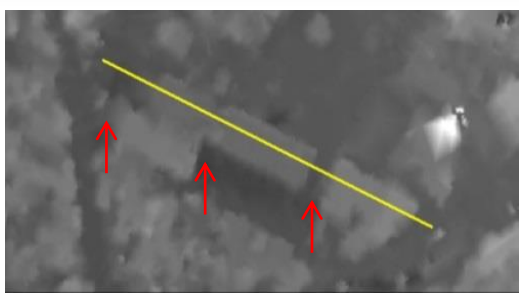
D  
S  
M



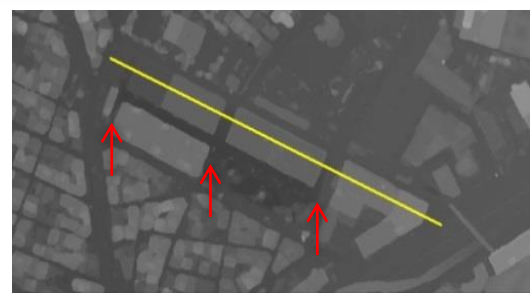
## DSM



Pleiades

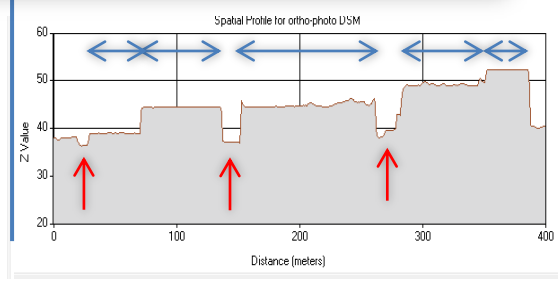
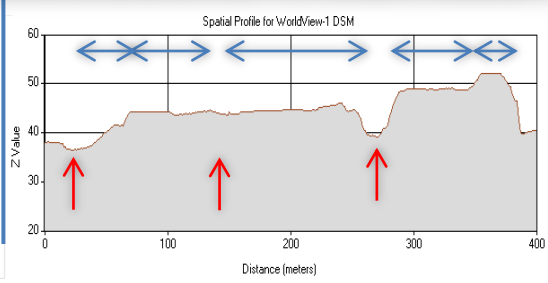
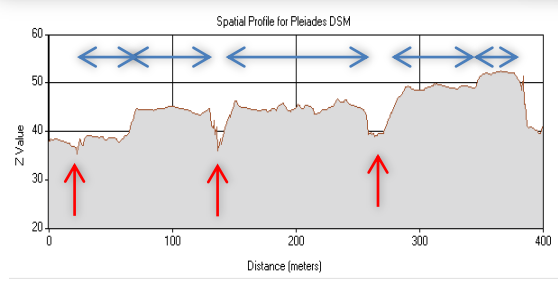


WorldView-1



Reference Data set

## TRANSECTS' PROFILES



The DSM derived from the Pleiades data processing better fits to the Reference data set



## OVERALL ASSESSMENT

### ☐ Buildings ( ~ 28.000 ) present/ common to all the data sets

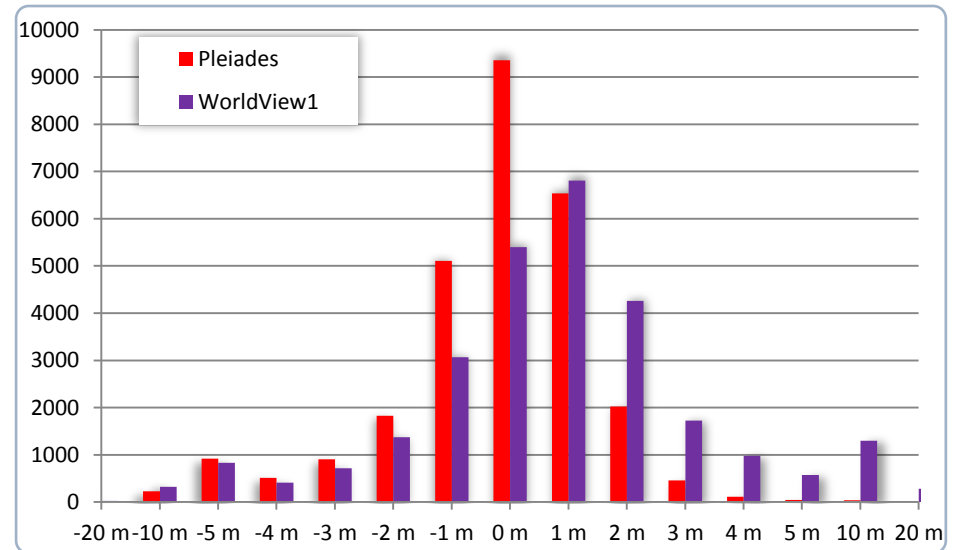
- ✓ Surface (height) difference calculation : *Z Error*
- ✓ Satellite data DSM towards the Reference Data set

## STATISTICS

### Z Error Analytical Data

	World View 1	Pleiades
Absolute values	2.05 m	1.37 m
Average Error	0.26 m	-0.83 m
Standard Dev	3.32 m	2.09 m
Range	-32.0 m to 30.0 m	-31.0 m to 13.5 m

### Z Error distribution



### ☐ Both data sets enable the production of “accurate” DSM

- ✓ Zero difference occurrences of the DSM resulting from the Pleiades data are almost twice as much as those resulting from the WV-1 data processing
- ✓ Narrower Z error distribution results for the Pleiades DSM





## ASSESSMENT per LAND COVER/ USE

☐ Buildings ( ~ 28.000 ) present/ common to all the data sets

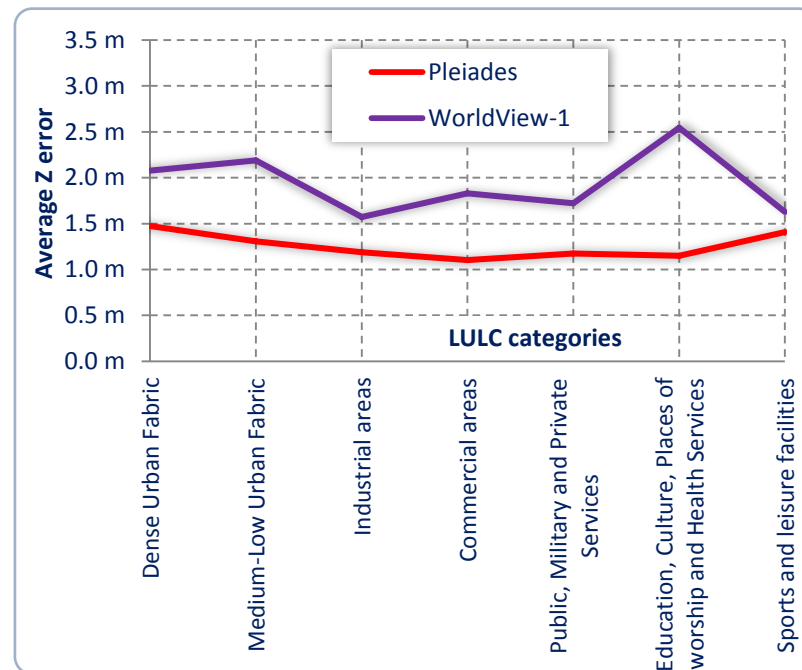
✓ Z Error Analysis for seven different types of Cover/ Use

## STATISTICS

Z Error Analytical Data

Land Use/ Cover	No Of Buildings	WORLD VIEW 1			PLEIADES		
		Mean (abs) error	MIN	MAX	Mean (abs) error	MIN	MAX
Dense Urban Fabric	14302	2.1	-23,2	19,6	1.5	-20,4	8,3
Medium-Low Urban Fabric	8613	2.2	-28,2	29,7	1.3	-21,6	5,9
Industrial areas	1479	1.6	-32,4	15,7	1.2	-18,7	13,4
Commercial areas	126	1.8	-16,2	10,5	1.1	-7,8	4,5
Public, Military & Private Services	2969	1.7	-25,0	18,1	1.2	-31,0	8,8
Education, Culture, Worship & Health	406	2.5	-20,0	26,5	1.2	-13,8	4,8
Sports & Leisure	56	1.6	-5,4	9,2	1.4	-11,3	6,7

Z Error distribution



☐ Similar Performance

**PLEIADES** 2 (0%) occurrences  $-20 \leq Z \text{ Error} \leq 20 \text{ m}$   
 23160 (83%) occurrences  $-2 \leq Z \text{ Error} \leq 2 \text{ m}$

**WV - 1** 36 (0%) occurrences  $-20 \leq Z \text{ Error} \leq 20 \text{ m}$   
 19770 (71%) occurrences  $-2 \leq Z \text{ Error} \leq 2 \text{ m}$



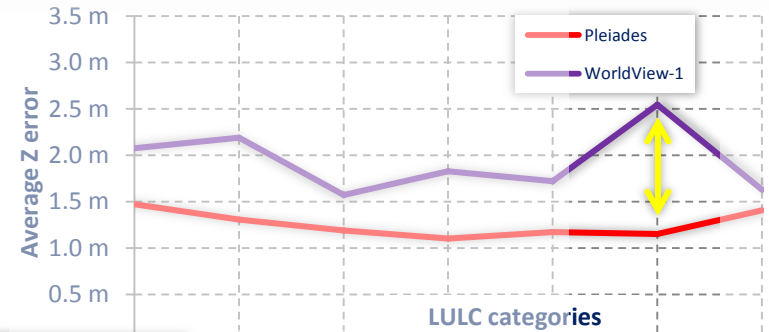
## BUILDINGS WITH NON – FLAT ROOFS

□ The LU/LC category : Education, Culture, Places of worship and Health Services

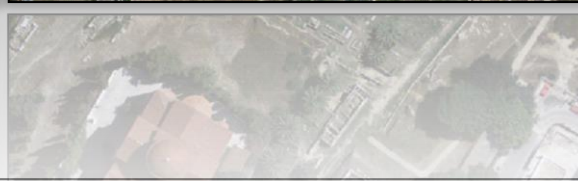
✓ it is characterized by buildings height differentiations

Education, Culture,  
Worship & Health

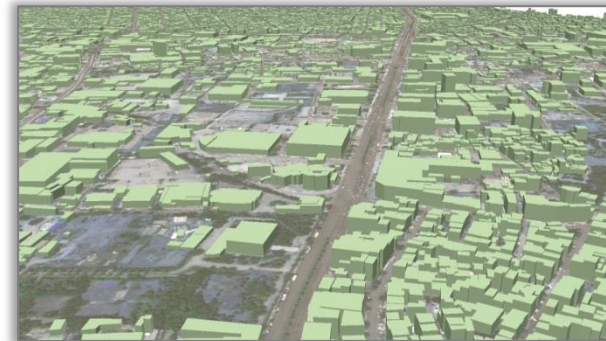
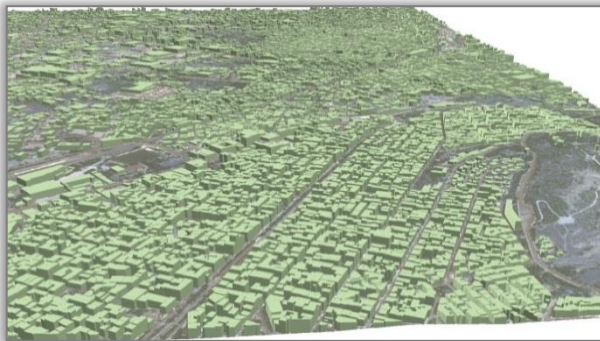
No Of Buildings	WORLD VIEW 1			PLEIADES		
	Mean (abs) error	MIN	MAX	Mean (abs) error	MIN	MAX
406	2.5	-20,0	26,5	1.2	-13,8	4,8



Medium-Low Urban Fabric  
Industrial areas  
Commercial areas  
Public, Military and Private Services  
Education, Culture, Places of worship and Health Services  
Sports and leisure facilities



- ❑ The accuracy for determining the buildings' - 'surface' - height resulting from DSM data produced by VHR satellite image stereo-pairs is of the order of 1,4 to 2,0 meters.
- ❑ The buildings' height assessment depends upon
  - ✓ pixel depth (11, 12, etc bits)
  - ✓ the acquisition geometry and conditions
  - ✓ The buildings' morphology (size, roof structure, etc).
- ❑ Accounting for the satellite data access and acquisition flexibility, their usage provides reliable data for urban areas monitoring.
- ❑ Valid buildings' data bases and terrain models facilitate the production of 3D buildings' models and changes' assessment





**Thank you for your attention !**



**02.04.2014, Toulouse**  
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